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STUDENT REPORT

AN ENGINEERING PARAPROFESSIONAL WORKFORCE FOR SPACE--THERE IS A BETTER WAY

MAJOR JOHN E. WHEELER 87-2710

"insights into tomorrow"

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TITLE AN ENGINEERING PARAPROFESSIONAL WORKFORCE FOR SPACE--THERE IS A BETTER WAY

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Submitted to the faculty in partial fulfillment of requirements for graduation.

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This paper provides the Air Force and space defense industry a framework for understanding a manpower concept called the engineering paraprofessional. Near-term engineering problems and rising manpower costs may prevent the accomplishment of several critical space goals of the 1990s. Areas of discussion include the paraprofessional concept, engineering manpower problems, current and future paratechnical applications, and potential government cost savings. The study concludes that a more efficient skill mix of engineers and paratechnicals can solve engineering shortfalls, increase productivity, and lower manpower costs. It recommends Air Force advocation of a more balanced contractor workforce, industry cooperation, and encouragement of a future study on the applicability of the paratechnical concept within the military structure.

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PREFACE

The purpose of this paper is to provide the Air Force and space defense industry a framework for understanding a manpower concept called the engineering paraprofessional. Near-term engineering problems and rising manpower costs threaten the accomplishment of many military space endeavors of the 1990s. Successfully employed in the Space Shuttle program, a more efficient skill mix of engineers and para-engineers can solve potential engineering shortfalls while providing a lower manpower cost alternative. This paper will discuss the paraprofessional concept, serious engineering manpower problems, current and future paratechnical applications, and potential government cost savings from the employment of a paratechnical workforce. This project was sponsored by Headquarters Space Division, Space Transportation System Program Office, Cargo Integration Directorate, in support of achieving future Air Force space goals through more productive means. The intent of this study is to encourage Air Force actions aimed at strengthening the space defense contractor manpower base through a more balanced skill mix of engineers and engineering paraprofessionals.

Due to a limited amount of subject information, this report relies heavily on both personal experiences and contacts. The author would like to express his sincere appreciation for the contributions of many dedicated individuals assisting me with this report: first, a very special thanks to my wife, Phyllis, for her patience and secretarial paraprofessional skills in typing this report; a personal acknowledgement to Mr. Lex Allen of Barrios Technology, Inc., for his support and assistance in suggesting document sources and editorial comments; Mr. E. L. (Gene) Davis and Mr. Jerry Yglesias of Barrios Technology, Inc., for their excellent written material and candid dialogue; Dr. Wallace T. Fowler of the University of Texas at Austin, who provided both support and professional advice to include several documents addressing the status of engineering education and manpower shortages; Mr. Ken Young, Mr. Larry Hartley, and Dr. Gregory Hite of the National Aeronautics and Space Administration's Johnson Space Center, for their keen insights and experiences in close association with a paraprofessional workforce; and, Dr. Randall C. Davis of Poquason, Virginia, for his timely and frank written letter on engineering manpower, and his sincere personal recommendations. The author would like to additionally thank the following military officers: Captain Abudl-Malik Freeman of the Headquarters Space Division Contracting Office for providing technical contract information concerning engineering manpower; Lt Col Warren Riles of Space Division for sponsoring this report, and providing current Air Force insights and recommendations during its development; Major Tim Bosse, US Army, ACSC student, for his generous time in providing editorial suggestions; and, Major Randy Blakelock, ACSC project advisor, for helping define overall project scope, direction, and soundness.

ABOUT THE AUTHOR

Born in St. Louis, Mo., Major John E. Wheeler received an ROTC commission in December 1972 and entered active duty in September 1973. Assigned to the Aerospace Defense Command's 1st Aerospace Control Squadron, NORAD/Cheyenne Mountain Complex, Colorado Springs, Colorado, he performed operational duty as a space systems orbital analyst leader in the Space Defense Center. In January 1979, following graduate studies at the Air Force Institute of Technology, Major Wheeler was assigned as an Air Force detailee to the National Aeronautics and Space Administration's Lyndon B. Johnson Space Center (NASA/JSC) in Houston, Texas. He held positions of Space Shuttle Orbital Operations Engineer, and Chief, Shuttle Deployment and Separation Operations for the Air Force's Inertial Upper Stage (IUS). While at JSC, he published a NASA document (JSC-17504) entitled "Orbiter/IUS Separation Sequence Design--Effects of IUS/Solid Rocket Motor Exhaust Particle Damage to Orbiter Surfaces." In March 1983 Major Wheeler was transferred to the Space Transportation System Program Office, Headquarters Space Division, Los Angeles, California. He served as Manager, Payload Flight Operations and Mission Planning, and was later selected as the Mission Integration Manager for the first Space Shuttle launch from Vandenberg AFB, California. Following graduation at Air Command and Staff College he will be assigned to the Air Force Element, DOD Project Office, APO, New York.

Major Wheeler's awards include the Meritorious Service Medal (one oak leaf cluster), the Lyndon B. Johnson Space Center "Group Achievement Award", and he wears the Master Space Badge. In March 1985 he was nominated by the Air Force as a Mission Specialist Astronaut candidate to NASA. His military education includes Squadron Officer School (correspondence) and Air Command and Staff College (seminar and in-residence). He has a Bachelor of Science Degree in Aerospace Engineering from Parks College of Aeronautical Technology of St. Louis University, and a Master of Science Degree in Astronautical Engineering from the Air Force Institute of Technology.

Major Wheeler is married and he and his wife, Phyllis, have two children, Karla and Jonathan.

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REPORT NUMBER 87-2710

AUTHOR(S) MAJOR JOHN E. WHEELER, USAF

TITLE AN ENGINEERING PARAPROFESSIONAL WORKFORCE FOR SPACE--THERE IS A BETTER WAY

I. Purpose: To provide the Air Force and space defense industry a framework for understanding historical and future aspects of a manpower concept called the engineering paraprofessional.

II. Problem: The Air Force space projects of the next decade involve the development of many new and critical technologies. Near-term engineering problems and rising manpower costs may prevent the accomplishment of several of these critical goals. Cost savings in engineering contractor personnel can be attained, and shortfalls avoided, if space defense contractors and the Air Force jointly support the employment of a more efficient skill mix of engineers and engineering paraprofessionals.

III. Data: Paraprofessional personnel perform an ever-increasing role in today's workforce. Countless examples demonstrate the interaction between professionals and paraprofessionals results in a more efficient, less costly, and higher quality workforce. The applicability of the concept to engineering has been extremely limited. Employed on a large scale in the early 1950s, it later underwent dramatic changes and almost totally disappeared. The most recent and successful employment of a paratechnical workforce can be found at the National Aeronautics and Space Administration's (NASA) Johnson Space Center in Houston, Texas. By analyzing this experience, the Air Force can better understand this lower cost manpower alternative, and more easily apply it to future military programs. The way this concept affects the engineering community can best be shown by first analyzing engineering education

CONTINUED

problems, industry shortfalls, and incidents of waste in available resources. All three areas pose significant problems for today's engineering space industry, but solutions are possible. This report was limited to a discussion of government contracts which exclusively solicit engineering manpower support services. By closely analyzing actual contracts of this kind, potential cost savings can be realized by utilizing a conservative engineer to para-engineer skill mix.

IV. Conclusions: To meet the challenges of space in the 1990s this country must change its way of doing business. "Engineering extenders" may provide the solution. Widespread integration of this workforce into the engineering community may prove to not just be an innovation, but also a necessity if complex operational and man-intensive programs such as the Strategic Defense Initiative are to survive. If cost savings from an actual three year contract can reach millions of dollars, the government savings from all eligible contracts could reach into the billions. Besides lowering costs, employment of paraprofessionals produces benefits for the engineering staff. They are relieved from routine tasks and made available for more productive and challenging duties. A key element for success is to provide the paratechnical workforce with the proper computer tools and environment. Additional results include increased job satisfaction, higher morale and motivation, greater workforce stability, and higher productivity in contributing to a stronger defense for the United States.

V. Recommendations: The United States Air Force must lead the way for government advocation of a more balanced skill mix of engineers and engineering paraprofessionals. Space defense industry cooperation is essential; they must be convinced this a practical means for strengthening their engineering manpower base. The Air Force and industry must next agree on a reliable plan for jointly applying the concept. The Air Force should also encourage a future study on the applicability of the paratechnical concept within its own military structure. Para-engineering training and utilization of noncommissioned officers in critically manned officer engineering fields is a viable answer to alleviate current and future Air Force shortfalls. Recent congressional directives aimed at reducing officer personnel strength make this an extremely relevant subject.

Chapter One

INTRODUCTION

BACKGROUND

> . . . the Air Force is entering an era unlike any in the past. The opportunities and challenges will be great. . . . The next quarter century will produce many more exciting advances in space technology, and the Air Force will continue its effort to capitalize on the efficiencies and advantages of space operations. But we will also need to capitalize on efficiencies and advantages in many other areas not even thought of today. . . . We need to look for better ways to do things, not fall back on the comfortable ways of the past (9:10).
>
> General Charles A. Gabriel
> Chief of Staff
> United States Air Force
> January 1984

The Air Force is indeed embarking on a new era in space where a seemingly infinite number of new and critical technologies will be designed, tested, and deployed. Additionally, the 1986 National Commission on Space stated, "the most critical technology [base for the future of space] is human support, which is both crucial and least understood, for it includes the durability of society in space" (5:45). The space projects of the next decade and beyond, which include a restart of the Space Shuttle program followed by full-scale operations, the Strategic Defense Initiative (SDI), National Aerospace Plane, US Space Station, and satellite launch and on-orbit operations, are already creating a highly competitive engineering job market. In order to compete for one of these lucrative contracts, aerospace firms will attempt to lure engineers away from their present jobs with higher salary incentives. As engineering costs continue to spiral, the Air Force may not be able to attain some of their crucial space goals in the 1990s (28:--) unless, as General Gabriel implied, it discovers a better way to utilize aerospace manpower.

PURPOSE

This project examines the use of a manpower concept called the engineering paraprofessional (or paratechnical). Cost savings in engineering contractor personnel for these near-term Air Force space projects can be attained if space defense contractors and the government jointly institute this paratechnical manpower concept. Having worked closely with engineering contractors for over eight years, the author has observed several cases of waste in which licensed engineers performed tasks better suited for trained paratechnicals. The author also benefited from working with a contractor's organization comprised of a balanced skill mix of engineers and paratechnicals. This organization provided services at a reduced cost to the government while increasing the mission capability of the National Aeronautics and Space Administration's (NASA) Johnson Space Center (JSC). This experience demonstrated that the engineering paraprofessional, as an arm or "extender" of engineering capability, is a concept whose time has come.

OVERVIEW

Chapter Two will define paraprofessional and cite some examples in industry today. This chapter will also discuss a brief history of engineering paraprofessional employment. Chapter Three will examine the quality of today's engineering education and the decline in available engineering manpower; furthermore, it will discuss misuses in the application of engineering manpower. Chapter Four will look at the NASA/JSC solution to engineering shortages on the eve of increased Space Shuttle mission requirements, and resulting cost savings from employment of a paratechnical contractor workforce. This leads to Chapter Five's analysis of the growth potential for paratechnical employment. Potential cost savings result if appropriate skill mix changes are created within the contract framework. Chapter Five further discusses future space applications for engineering paraprofessionals and potential difficulties and solutions. A fundamental premise to this project is that increased engineering productivity does not have to mean an increase in professional engineers; it merely requires more effective employment of available contractor resources.

To further emphasize the need for a balanced engineering force it should be noted that in the last three to four years "space has been the most rapidly expanding segment of the aerospace industry's business. . . . Space sales will top the $20 billion level for the first time in 1986, . . . and military space [is] the fastest growing element" (1:13). If the Air Force wants to maintain its strong leadership role in space technology pioneering, new ways for utilizing contractor manpower must be found.

Chapter Two

The PARAPROFESSIONAL CONCEPT

DEFINITIONS

". . . so many degreed professionals have stereotyped views of what a paraprofessional is" (22:2).

To insure the reader has a sound understanding of the paraprofessional concept, this chapter discusses definitions, examples, and some history of paraprofessional utilization. The dictionary defines paraprofessional simply as "one who assists a professional." First of all, what is a professional? A professional is interpreted to be anyone who has received a bachelor's or technical degree from a university or technical school, or who has acquired the equivalent skill through technical experience and training. In the space industry, these are engineers, mathematicians, system analysts, computer programmers, and professional business administrative personnel. The paraprofessional is defined as a person who has graduated from high school or college with a nontechnical degree, has received specialized technical training, and demonstrated technical proficiency in his/her assigned area. Training prepares the paratechnical to perform a professional task that has been structured to fit a lower skill level. "The paraprofessional is relegated to auxiliary, technical functions which, though helpful and important, are not of the same caliber as the professional [tasks]" (16:18). Paraprofessionals are often defined in terms of the specialized work they perform, e.g., data processing, engineering aide, etc., than in terms of their education or training. They can expand the capability and productivity of engineers by carrying out many time consuming and repetitive tasks (23:6).

INDUSTRY EXAMPLES

One only has to look at industry today to quickly surmise ". . . that competence and quality performance are not necessarily products of university degrees" (16:17). Paraprofessional personnel perform an ever-increasing role in today's workforce. Paramedics, nurse practicioners, surgical and dental assistants, teacher aides, library paraprofessionals, and law office paralegals are extremely capable examples. While not all inclusive, this list demonstrates the growth of paraprofessionals in the United States and illustrates that the interaction between professionals and paraprofessionals can result in a more efficient and higher quality workforce. In the space engineering field, a good example of paraprofessional use occurred at Barrios Technology, Inc. of Houston, Texas. The applicability of the concept arose from new Space Shuttle requirements and was originally conceived in 1978 by Mr. E. L. "Gene" Davis and Mr. E. C. Lineberry of NASA/JSC. From a small group of six test-bed NASA paratechnicals, this idea today is the trademark of a company of over 200 engineers and paraprofessionals. The wide variety of routine tasks they perform for Space Shuttle operations and Space Station design has demonstrated that the training and utilization of non-engineers, provided with an extensive interactive computer system, can augment the need for professional engineers. This experience will be discussed in detail in Chapter Four.

EMPLOYMENT HISTORY

The employment of engineering paraprofessionals is not a new concept. The practice came into wide-scale use in the late 1940s to early 1950s. The following background information explains this practice and why during the mid-1950s the concept changed. This information was extracted from writings and personal conversations with Mr. Gene Davis who is now employed by Barrios Technology, Inc.

In the late 1940s, most of the major engineering firms in the United States had strong apprentice schools attached to their companies. Each company engineer had a small cadre of support technicians educated by these schools (e.g., draftsmen, model-makers, welders, electronic technicians, and machinists). During this time, Mr. Davis worked for the Langley Laboratory supervising a section of ten engineers and sixteen technicians. Today, however, most of the apprentice schools no longer exist as a result of dramatic changes in 1954-1957 in military procurement contracts for weapons development. These new contracts were cost plus and awarded on the basis of potential technological competence. This actually meant contracts would be based on the "skill level" of a company's employees. The corporate personnel departments indentified this trend and shifted recruiting strategies. Most importantly, a supervisor's salary depended on the number of engineers, mathematicians, or physicists, he managed. Supervisors screened new employees not just for the present vacancy, but also evaluated potential to include a higher technical competence level. Unfortunately, this personnel policy still exists at several of the leading aerospace firms in this country. The pressures became so strong to upgrade technicians to engineers that one company reclassified more than a thousand of its employees in a one week period: contract dollars depended on it. Over a single weekend another company reclassified all members of its Drafting Division from draftsmen to design engineers and changed the department's name to Engineering Design Division. These employees went home on Friday as draftsmen and returned Monday as engineers! By 1957, however, the military tightened its purse strings. As a result, hundreds of the non-degreed engineers were laid off, while degreed engineers now found themselves sitting in drafting departments (22:3-4; 24:--).

Although the military eliminated this procurement practice in the late 1950s, it was too late, the damage had been done. Most of the jobs in today's aerospace industry are done by degreed technical people. The elimination of numerous engineering technicians (except for hardware repair, maintenance, and similar functions) as a result of the 1957 cutbacks has changed the status of the engineering professional (22:4). Unless industry moves toward a reassessment of the best skill mix for the job at hand, this status is unlikely to be restored.

SUMMARY

One of the most important points to remember is the employment of engineering paraprofessionals does not mean engineers will be losing jobs. Paratechnicals are not used in place of engineers; rather, they become "engineering extenders." When one begins to focus on this idea as a non-threatening concept, the benefits are apparent: the development of a highly motivated workforce with the potential to produce high quality and timely products.

"Most educators claim that practical or [in-house] experience is the most important aspect of the educational process. It is apparent that students learn most from practical experiences rather than lectures" (16:17). It is essential the paratechnical be given adequate training and provided the right tools and environment to be effective. Hopefully, this chapter enabled the reader to better understand the use of engineering paraprofessionals and why this workforce faded from the military contractor engineering arena in the mid 1950s. This alternative source of manpower can be a cost-effective and efficient means of accomplishing tasks that are well-defined, proceduralized, and repetitive in nature. In times of engineering shortfalls, it becomes an even more critical and invaluable resource.

Chapter Three

NEAR-TERM ENGINEERING PROBLEMS

What additional capabilities can paratechnical manpower provide to an engineering corporation? If there is a big enough pool of engineers for the corporate workload, then wouldn't this concept threaten the engineer's employment future? These are very pertinent questions, but if there is an engineering threat it would have to be based on the assumptions that there are: 1) no engineering education problems, 2) no engineering industry manpower shortages, and 3) no waste in the available engineering manpower. To be convinced of a non-threat need for engineering paraprofessionals, this chapter will discuss the above three assumptions, demonstrating they all pose significant problems for today's engineering industry, particularly in the space business. The employment of engineering paraprofessionals in a modern aerospace workforce can best be initially examined through this framework.

EDUCATION CRISIS

To meet the challenges in space in the next decade, a continuous output of well-educated and trained aerospace and astronautical engineers will clearly be required. The biggest challenge to this requirement is the maintenance of highly qualified faculty members in our engineering institutions. The National Research Council (NRC) recently claimed "the lack of sufficient faculty is the most important factor currently limiting attempts to increase the quality, scope and number of engineering programs" (6:12). Another report estimated the shortage of qualified engineering faculty to be approximately 1800. If this figure were adjusted to 1968 teacher-student ratios the shortage would climb as high as 5000 (19:8). The American Association of Engineering Societies claimed the faculty shortage problem was long-range and intensifying because of the decreasing number of native-born engineering doctoral students. This lowers the pool of potential faculty members needed to maintain quality engineering education (3:85). In fact, "40 percent of graduate engineering students are foreign nationals on temporary visas who, presumably, do not intend to remain in the US" (7:6). While the number of advanced degrees awarded to the foreign nationals almost tripled during 1968-1982, the number of doctoral degrees awarded to US citizens declined by 42 percent (19:8). A number of factors contributed to this decline, but central to the issue is marketplace demand for engineers. Attractive job offers are providing immediate return for a student's investment (19:8). The NRC illustrated this fact by claiming the current problem of maintaining faculty is exacerbated by industry luring away both faculty members and graduate students with high-paying jobs (6:12).

Some of the strongest statements were made in early 1986 by the National Science Board which said that the nation's undergraduate programs in science, mathematics, and engineering are no longer meeting the needs of the country due to a decline in program content and scope. Serious long-term threats potentially exist to the nation's defense strength, industrial and economic competitiveness, and its scientific and technical capacity (13:153). The board went on to say that faculty members in many cases were unable to maintain their teaching skills, currency within their disciplines, and command of new technology. Serious shortages of qualified faculty were noted, especially in the engineering disciplines (13:153).

This technical education problem is not just limited to our universities. Severe shortages also exist in high school teachers qualified in mathematics and science. This problem not only affects students wishing to pursue an undergraduate engineering degree, but contributes to a technically uneducated populace unable to contribute in an increasingly technological world (19:9). Employment of these non-technical students as engineering paraprofessionals could foster growth and contributions that might otherwise remain untapped.

The Quality of Engineering Education Project in its final report in 1986 best summed up why the engineering faculty problem is such a critical issue. As our society changes from an industrial-age economy to an information-age ecomomy, engineering also undergoes fundamental changes. But as new technologies emerge with shorter and shorter transition times, an up-to-date and competent engineering faculty becomes extremely hard to guarantee (14:62). "The United States' scientific strength and technological capability depends directly on the quality of the scientific education received by its students and on the number of students who enter *scientific fields*" (15:1). If both of these factors are declining then what are the solutions? Should the federal and state governments throw more money at engineering education as done in the past, or should new ideas be explored on how to better utilize the growing pool of non-technical personnel in a dynamic world of technological change? The problem of engineering education is serious enough, but coupled with an engineering industry manpower shortage it becomes even more critical.

INDUSTRY MANPOWER SHORTAGES

Over the last four years several reports have indicated that engineering manpower levels in the United States are experiencing significant shortfalls. In 1982, the National Science Foundation stated that industry manpower shortages were most critical in the engineering areas (15:3). Another report in 1984 projected the 1987 shortages of aeronautical and astronautical engineers in all fields will vary from 15 to 45 percent, representing approximately 10,000 to 35,000 personnel (19:9; 18:19). Although 60 percent of all aeronautical/astronautical engineers will be employed in defense-related activities by 1987 (18:7), the shortage of these Department of Defense (DOD) contractor engineers will be greater than 10 percent (19:32).

Future projections only dim an already bleak picture. The Bureau of Labor Statistics projects the demand for scientists and engineers to increase by 40 percent between 1978 and 1990. During the same period there will be a 10 percent decrease in bachelor of science engineering degrees (15:4). The conclusion is clear--a strong labor market demand coupled with a decrease in available aeronautical/astronautical engineers, will have a serious impact on the level and direction of future defense industry projects in space.

Another point worth mentioning is that between now and the year 2000 approximately 30-40 percent of the current engineering base will retire (26:--). Their replacement will be next to impossible if the above trends continue. In addition, much of the shortfall predicted between now and the 1990s is due to the tremendous loss in engineers between 1971-1976, a period which followed the Apollo moon missions and was prior to the Space Shuttle buildup. If a large percentage of these engineers are now in new career fields, then the long-term answer is not just to educate and hire more engineers. Interestingly enough, the University of Texas at Austin experienced a dramatic decrease in engineering student enrollments during 1971-1976, from a norm of 500-600 students per year to a low of 125 (26:--).

This engineering manpower shortage is most critical in the major disciplines employed by DOD space contractors, e.g., the aeronautical and astronautical fields (18:7,19). This will cause serious future repercussions, unless some new workforce of non-engineers, trained in technical disciplines, can help to fill the gap.

APPLICATION OF RESOURCES

In thirteen years of space experience as as Air Force aerospace and astronautical engineer, the author has seen several misuses of available engineering manpower in the workplace. Most of these occurrences are in the performance of clerical/administrative duties, or in repetitive flight design and mission operations tasks. These observations are shared by others, as seen in the two examples below:

> It seems that most professionals (dentists, lawyers, doctors) make more efficient use of their valuable time and hard-earned training than engineers. Everyday I see engineers typing their own reports, making copies, making travel and meeting arrangements, chasing down supplies or walking paperwork through the system. . . . Any [corporate] expansions, reorganizations or new funds are earmarked for engineers, not for support. . . there is no shortage of engineers, just a colossal waste of engineering time and talent. . . . How much longer can the engineer afford to pretend he doesn't realize how much his time and talents are being wasted. . . ? This is a vital issue that is being swept under the carpet. It is an issue that affects us as a nation today more than ever. . . . If we are to compete with the rest of the world, . . . we must use our valuable engineering talents wisely (4:92).

Others share this opinion concerning engineering productivity:

> If you walk into a dentist's office, you are met by a trained receptionist. . . [and prepared by] a trained dental technician . . . . Everyone, especially the dentist, maximizes their productivity. In a business-as-usual engineering office you will find 20 engineers and only one highly trained support person. . . a secretary. She's so busy that I've seen trained engineers standing in line to copy papers on a machine, or to draw a pencil from the supply store. . . . And it's claimed we have a shortage of engineers. What we have is a lack of imagination in how to do business. Every time I hear "we need more trained engineers," I groan. Anybody out there have any courage (8:140)?

Although the above two examples may seem a bit overstated, they illustrate a point. In addition, the author has personal examples of engineering manpower misuses. DOD contractor engineers were needlessly redesigning Space Shuttle/payload deployment and separation procedures which had already been standardized by NASA/JSC, and were being followed by production flight design paraprofessionals. Space Shuttle crew activity timelines were also being developed by DOD contractors without full knowledge of NASA timeline constraints, resulting in numerous corrections and revisions. When Shuttle launch delays occurred complete timeline revisions were usually necessary, which further magnified the problem. The area of Shuttle trajectory design, coupled with a computer system for Shuttle flight planning, the Flight Design System (FDS), had other instances of misused engineering manpower. Part of this was due to inherent DOD duplication of NASA effort, but the bottom line is that all of the FDS work could have been done at a much lower cost through the use of a paratechnical workforce. The author made numerous attempts to remedy the problem by pursuing a paraprofessional-type contract for FDS planning tasks, but was always met with Air Force management resistance in embracing the concept directly. Instead of a direct, cost-savings contract, the preferred solution was to subcontract the paraprofessionals to other contractors. This meant the Air Force had to pay a prime contractor's higher price in order to employ the paratechnical contractor's workforce. This higher price was the prime contractor's fee for subcontract origination, administration, and profit. Since the paraprofessional concept was designed to save the government money and not to be a cost burden, this solution was extremely counter-productive. Based on the author's experience this cost burden was at least 25 percent or higher (contract proprietary concerns prohibit quoting an exact figure or source).

Another area of engineering manpower waste can be found at the numerous USAF satellite control complexes. Usually these mission control facilities are exclusively managed and operated by one DOD contractor who employs technical engineers for all the tasks. As will be shown in Chapter Four, paratechnical personnel are capable of operating a significant portion of backroom realtime mission console positions under engineering supervision. This change in manpower usage has tremendous potential for cost savings.

In situations where there is a misapplication of manpower, one of three directions is almost always taken by the engineer whose time is being misapplied. The engineer will: 1) take longer time than necessary to complete a task, making the problem and its solution too complex in order to remain challenged and interested, 2) leave his job for a new and more motivating environment, or 3) begin working on other personal interests on company time (24:--). All of these steps result from the degradation of engineering professionalism in the work environment. Immediate solutions must be implemented to free the engineer from menial tasks, raise self-esteem, and insure his/her skills are applied to the difficult problems, such as design, system concepts, analyses, research, etc. (24:--). The use of engineering extenders, or paratechnicals, can solve this productivity problem.

SUMMARY

This chapter pointed out three near-term engineering problems and how the employment of a paratechnical workforce can eliminate them. A brief summary shows that despite increasing concerns on the quality of engineering education, the technical level of the aerospace workforce can still be raised; engineering manpower shortfalls can be filled, and an increase in the professionalism in the existing engineering base can be attained through the use of engineering paraprofessionals. Hopefully, the reader is convinced of the critical need for an alternate source of manpower for today's increasingly technological space endeavors. But how can this concept be resurrected? As was shown in Chapter Two, aerospace firms abandoned it in the mid 1950s. Chapter Four will discuss its revival at NASA/JSC in the late 1970s on the eve of an operational Space Shuttle program.

Chapter Four

ENGINEERING PARAPROFESSIONALS AND THE SPACE SHUTTLE

HISTORY

In 1978, NASA/JSC faced a profound engineering manpower dilemma, particularly in the area of Space Shuttle mission planning and flight design. How does an organization move from supporting four to six Shuttle flights a year to an operational era goal of 24 flights a year? The increased cost in manpower seemed enormous; additionally, this workforce was not even available. During the Mercury, Gemini, Apollo, Skylab, and Apollo-Soyuz programs, NASA formed flight design teams as early as three years before a mission. Based on this concept, if the Shuttle were to fly an average of twice a month a new team of flight designers would be formed every two weeks. The result would be 72 mission design teams in existence at the same time. If an average of six planning engineers would be required each flight, then the manpower level just to do flight design (trajectory, proximity operations, consumables, documentation, etc.) could reach over 400 engineers. JSC/Mission Planning and Analysis Division (MPAD) management analyzed the problem and agreed many of the flight design tasks were repetitive. This led to the conclusion that the documentation process could be standardized, and next to the creation of a computer-based flight design system (the previously mentioned FDS) as the engineering tool to produce all of the Shuttle mission products (23:1-2). The increased manpower levels earlier feared were quickly dismissed, but a new problem emerged. Wouldn't engineers tire and become bored with producing standard documents in a repetitive environment with few challenges? Furthermore, was a new engineering skill mix required?

Mr. E. L. "Gene" Davis and Mr. Ed C. Lineberry of JSC/MPAD solved this problem by proposing the training and employment of an engineering paraprofessional team. In 1978 and 1979, Mr. Davis managed two six-month pilot projects, each of which utilized a small number of paratechnical personnel. The training and operational results were a success and led in 1980 to the award of a Flight Design Support Services Contract to a newly formed paratechnical company called Barrios Technology, Inc. In a high flight rate environment, this contract provided NASA with mission-unique data base management, flight design integration, and quality flight profile products.

EMPLOYMENT METHODOLOGY

Barrios has trained and employed over 120 para-engineers in its short six year history. The concept has been highly successful, reducing costs while still maintaining required manning levels and high quality products to support the Space Shuttle flight rates. Cost reductions occurred primarily in those tasks requiring routine, repetitive, labor intensive, well defined, and well documented skills. The Barrios workforce is led by a team of engineers who manage and technically direct the para-engineers (21:1). The actual engineer-to-paratechnical skill mix is roughly 1:4. Every Barrios paraprofessional is required to have at a minimum a high school diploma with a good math and science background. Many have college degrees in non-technical fields. But most importantly, each new employee is screened with a math competency test and required to attend a four to six month full-time formal training program. The course curriculum was prepared by the University of Texas Center for Research and is conducted by qualified Barrios instructors. Training is the critical first step in developing a paratechnical workforce (21:2). This program initially provides student familiarization with Space Shuttle-unique acronyms, terminology, and basic orbital mechanics concepts. Students are then introduced to specific computer operating systems and procedures that they are likely to operate. This generalized training is further supplemented with specialized classroom and on-the-job training so that the paratechnical becomes familiar with all the tools and required tasks.

The interface between the Barrios paraprofessionals and engineers (both NASA and contractor) is well defined. In the flight design process, the paratechnical acts as an interface between an engineering team and the computer-based flight design system, FDS. Without exception, paratechnicals are supported by a supervisory group of engineering professionals. Intermediate supervisors range from personnel with good organization skills and technical experience to senior paratechnicals. This results in an overall team of several paraprofessionals with varying experience, seniority, and specialities, all managed by a qualified engineer (21:2).

TASK DESCRIPTIONS

Since the award of a consolidated Space Transportation System Contract (STSOC) by JSC in 1985, many other NASA contractors began employing their own cadre of para-engineers. Their primary utilization is in production flight design for NASA, commercial, and DOD Shuttle missions. This includes the on-orbit trajectory design products, administrative tracking and scheduling support, data base maintenance, and reproduction and distribution of flight planning products. They are also involved in other documentation intensive tasks, such as compiling the on-orbit Flight Data File from NASA and payload inputs. Engineers are more widely utilized in the critical areas of Shuttle ascent and descent design and in complex on-orbit proximity operations between the Shuttle and a payload, e.g., deployment, separation, rendezvous, stationkeeping, fly-around, approach, and grapple. As more Shuttle software becomes standardized, varying levels of paratechnical support are also possible for these tasks.

For approximately two years a Barrios para-engineering workforce has also been involved in computer software conversion and rehosting for MPAD. Primarily this has required the conversion of non-standard fortran code to a newer, more portable version, and the rehosting of the software onto new computer systems. Software configuration control, validation/verification, and some documentation has also been included in this effort. The paratechnicals are directed by software experts and developers who, in most cases, perform the final acceptance testing.

In the Mission Operations Directorate at JSC, paraprofessionals are now performing the routine scheduling and data base maintenance activities for the Crew Activity Planning System (CAPS). This system produces the previously mentioned Shuttle activity timelines that the astronaut crews follow while on-orbit. The nonstandard planning activities and real-time Mission Control Center support functions are still performed by engineers because of the nonroutine and critical nature of the work. During real-time operations the Shuttle ground navigation function has experienced an increasing level of Barrios support since the fifth Shuttle mission. Initially they performed only a data-entry function, but gradually have assumed more responsibilities as procedures became standardized and certain support functions became routine. Barrios developed software and standardized procedures and training materials which allowed replacement of engineers during non-critical mission phases. Approximately one-third of the ground navigation mission engineers have been freed up for more critical tasks at considerable cost savings to NASA. As procedures and software have become stable in the area of Shuttle postflight reconstruction, paratechnicals have been able to replace most of the engineers working on this task. A small core of engineers continue to oversee the work, provide quality assurance checks on the final postflight product, and perform any nonroutine analysis required.

NASA's latest project, the Space Station, is supported by 60 Barrios paraprofessionals at the JSC. Prospective customers (payloads) submit requirements for Space Station usage, and once approved, they are entered into a Mission Requirements Data Base by input-output clerks (NASA insures the validity of the data). This function requires a little more engineering and software programming knowledge than a computer operator or traditional clerk would possess, and has proven very useful and cheap in terms of cost. Paraprofessionals are also assisting engineers in the development of integrated operational scenarios for the Space Station, including how they can best be documented and linked together in an event timeline (29:--). Barrios has recently begun operations in Washington, D.C., assisting NASA Headquarters in Space Station program support activities. As the Space Station moves from a requirements development and mission planning phase to an operational phase, the utilization of paratechnical support is assured to grow.

COST COMPARISON

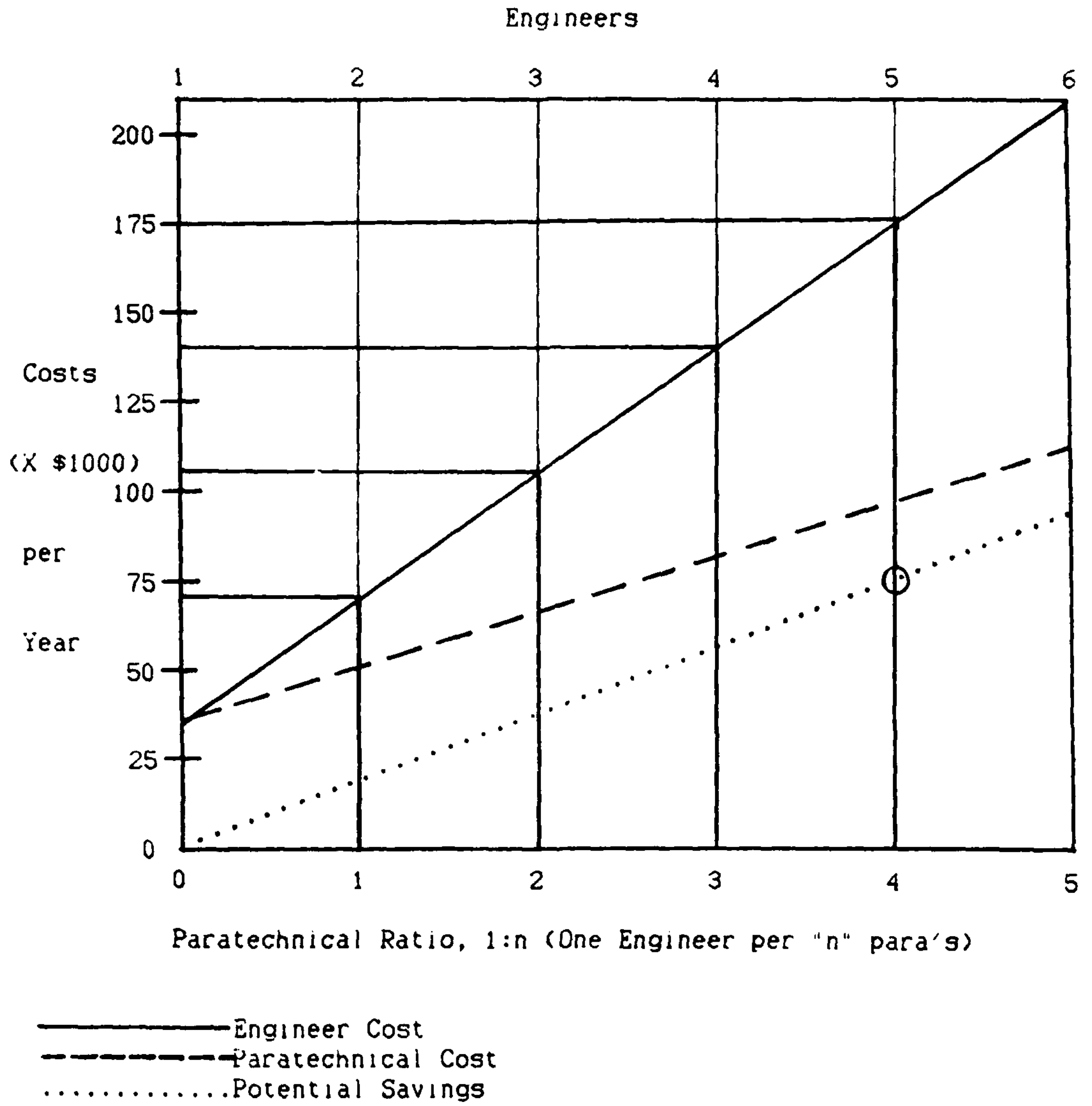
Potential cost savings which can be achieved by employing a paratechnical workforce are seen in Figure 1. This information was obtained from Mr. Jerry Yglesias of Barrios Technology, Inc. (21:6). Note that these direct labor costs do not include contract burdening, e.g., overhead, general and administrative costs, and fees. The inclusion of these figures would result in even higher savings since they are based on the total direct labor costs. Engineering costs were assumed at $17/hour (approximately $35,000/year) and paratechnicals at $8/hour (approximately $17,000/year), and each paratechnical team was assumed to have one engineering professional manager. The number of engineers is depicted on the top scale, in comparison to a paratechnical ratio, 1:n (one engineer per "n" para's) on the lower scale. Utilizing the average Barrios ratio of 1:4 it is shown from Figure 1 that approximately $75,000 would be saved over a one year period by employing one engineer and four paraprofessionals in lieu of five engineers (21:6).

A discussion was held with Mr. Larry Hartley of the JSC Mission Support Directorate in an attempt to quantify the direct NASA cost savings over the last five years from the employment of Barrios Technology, Inc. Three areas of employment were discussed: software conversion and maintenance, flight design, and management. The latter yielded no savings as it consisted of engineering professionals. Results showed an approximate six million dollar manpower savings to NASA from October 1981 to October 1986, which was distributed almost equally between software conversion and flight design. Mr. Hartley determined this figure by taking the $30,000 difference in the rate charged by a professional (approximately $65,000; unlike Figure 1 this includes labor <u>and</u> contract burdening) versus a paraprofessional (approximately $35,000), and multiplying it by the five year contract total of 200 man-years, resulting in a six million dollar savings (27:--).

SUMMARY

This chapter has shown that paratechnical employment by a government agency (NASA) does provide a lower cost manpower alternative in the areas of production engineering and routine procedural-type operational support. The three most important lessons learned from the NASA workforce environment are: 1) paraprofessionals must. . . "have close supervision and quality assurance checks by technically competent engineers," according to Ken Young, Chief of MPAD's Flight Planning Branch (29:--); 2) they must be provided with adequate training and certification steps in preparation for a position- specific task, and 3) they must be provided with the right tools and environment, e.g., an FDS-type production computer system which is mature, highly interactive, user-friendly, and well documented. Mr. Young continued with another lesson learned concerning employee turn-over rate. Initially feared by MPAD to be excessive, the paraprofessional attrition rate has not proved to be a major difficulty (29:--).

The engineering paraprofessional is now a new member of the NASA Space Shuttle and Space Station teams. This experience demonstrated paratechnicals and engineers can work extremely well with one another if the above three provisions are followed. Appropriately applying this concept to other government engineering manpower contracts is the next challenge of the government and aerospace industry.



- Engineers at approximately $17.00/Per Hour*
- Paratechnicals at approximately $8.00/Per Hour*
- Paratechnical Teams have one Professional Manager (Engineer)

* Does not include cost of contract burdening

Figure 1: Direct Labor Cost Comparison (20:6)

Chapter Five

GROWTH POTENTIAL FOR PARATECHNICAL EMPLOYMENT

GOVERNMENT ENGINEERING MANPOWER CONTRACTS

When the US Government solicits a Request for Proposal (RFP) on a new engineering contract there is always a section discussing the direct labor staffing requirements for the length of the contract. This section is sometimes very specific in addressing the required skill levels for each category of tasking, while at other times it is not. In no circumstances (known to this author), other than the NASA/JSC example, has a government RFP requested skill mixes of engineering manpower by using the terms of professional and paraprofessional. The Flight Design Support Services RFP which JSC solicted in 1980 was very precise on this skill classification. This section of the RFP is shown in Table 1 (17:7). Although this type of contract is somewhat unique to NASA/JSC, it does show how a government agency can request an appropriate skill mix for a specific task.

There are obviously thousands of government contracts awarded each year requiring some level of engineering, from research and development to actual fabrication, testing, and delivery of hardware. Although concept applicability is possible across this spectrum, this chapter will only discuss those contracts which exclusively solicit engineering manpower support services.

Two representative contracts were obtained from the USAF Systems Command/HQ Space Division Contracting Office. Avoiding any proprietary information, both can be described as space satellite launch and integration engineering support services contracts. Neither of the government RFP's which solicted these two contracts specifically requested an engineering skill mix of professionals and paraprofessionals. One of the contracts responded with a proposal defining an engineering hour as an "exact quantitative measurement performed by engineering personnel engaged in creating and/or regulating the prime technical activities of the contract" (20:--). All work was assumed to be done by engineers with no provisions for paratechnical personnel. The cost of this engineering hour did vary depending on the particular task. Further sections of the contract listed the different tasks which when equated to a man-year cost ranged from a low of $46,000/year to a high of $90,000/year (including overhead and fee). The average man-year cost was approximately $64,000, almost exactly the $65,000 professional cost per engineer used in the NASA/JSC example in Chapter Four (20:--).

Skill Classification	Function	MYE * 1st Year	MYE * 2nd Year
Project Manager	Training	1	1
Professional	Flight Design Integration	2	2
	Consumables	1	1
	STS Systems & Constraints	1	1
	FDS Facilities	1	1
	Data Base Management	1	1
Paraprofessionals	Flight Design	17	34

There are three levels of paraprofessionals, entry (trainee), journeyman, and lead designers. It is anticipated that the level-of-effort will escalate for the 5-year period as shown below.

Skill Classifcation	MYE Contract Year 1	2	3	4	5
Project Manager	1	1	1	1	1
Professionals	7	7	10	15	20
Paraprofessionals	17	34	50	75	104
	25	42	61	91	125

* Man-Year Equivalent equal to 2,080 hours, including training and paid leave.

Table 1: JSC Flight Design Support Services RFP Skill Mix (17:7)

The second contract obtained from Space Division stated that the required personnel for the contract will have "expertise in the designs and operations of. . . [specific items] identified in the Statement of Work, and shall have the ability to interface/communicate with members of the. . . technical community" (20:--). It further defined the different tasks to be performed but made no mention of engineering skill levels required. Costs of these different tasks ranged from $143,000 to $174,000/per man-year ($154,000 was the average). Obviously, this contractor found it necessary to provide engineers of the highest skill and technical levels.

Could these two contracts have benefited from the use of paratechnical personnel? If the Air Force had more closely looked at the individual contract tasks and requested in the RFP that the contractor respond with appropriate skill mixes of professionals and paraprofessionals, the contractor's response might have been different. The potential cost savings could likewise have been substantial.

POTENTIAL COST SAVINGS

A simplified and conservative approach to quantify potential cost savings in utilizing engineering paraprofessionals will be shown in this section. Table 2 addresses the two Space Division contracts. The assumption is made that the skill mix of those two contracts could have conservatively been a 3:1 (engineer:para-engineer) mix instead of 100 percent engineers. For any applicable contract, this means 25 percent of an aerospace firm's workforce would have to be paratechnicals. This percentage would vary from contract to contract, but could be as high as 80 percent, if the RFP described a contract similar to Barrios'.

	Avg. Man-Year Cost	3:1 Mix Cost*	Man-Year Savings Per Man $, (% saved)	3 Year Job /100 Man Savings
Contract 1	$ 64K	$ 57K	$ 7K (11%)	$2.1M
Contract 2	$154K	$124K	$30K (19%)	$9.0M

* 25% of workforce billed at $35,000 paratechnical man-year rate, thus lowering average man-year cost.

Table 2: Example of Contract Cost Savings

These figures are approximate, but when further multiplied by the total number of contract engineers the savings become quite substantial. If each contract was assumed to last three years and employ 100 personnel the resulting savings would be $2.1 and $9.0 million, respectively (See Table 2). Due to the nature of these contracts, the author proposes that it is not unreasonable to assume that a 25 percent paratechnical workforce (under engineering supervision) could have accomplished the contract tasks as well as 100 percent engineers. This would have resulted in actual contract savings worth millions of dollars to the Air Force.

Expanding this example, an assumption is made that approximately 3000 government contracts currently exist worldwide requiring similar engineering manpower services. Of those 3000 contracts, it is conservatively estimated that only 50 percent are of a nature that could utilize the benefits of paratechnical personnel. Assuming a 3:1 skill mix, 100 personnel per a three year contract, and a $65,000:$35,000 engineer to para-engineer yearly cost, the savings from one of these contracts would amount to approximately $2.25 million. Multiplied by the 1500 existing eligible contracts the overall government savings would total almost $3.4 billion dollars over the three year period, or approximately $1.1 billion dollars a year. This amount would have to be decreased by the cost of creating and maintaining an effective training program for the paraprofessionals, but the net savings would still be quite a significant figure.

Because of the conservative approach taken, these savings are not unrealistic. As was pointed out in Chapter Four, the Barrios skill mix is 1:4, which would result in even higher savings. Since this mix is appropriate for a paratechnical firm, the more conservative figure of 3:1 was used in this report. The author admits the approach taken here was simplistic, but the need existed to somehow attempt to quantify possible future dollar savings. If the government will begin to better analyze the engineering tasks needed and request specific skill mixes of para's and professionals, the resulting cost savings will make it possible for the Air Force to pursue space projects currently being abandoned, or likely to be abandoned, in the near future.

FUTURE APPLICATIONS

There are numerous functional areas for paratechnical employment in the DOD space defense contractor industry, some of which have already been discussed. First of all, early consideration must be given to operational concepts and approaches, as well as system-user requirements. When a program reaches its operational phase and achieves stability, the greatest benefits from a paratechnical workforce are realized (24:--). Secondly, in specifying particular paratechnical tasks it is always important to analyze the amount of engineering judgement required, and the level of automation built into a user system. Following defined procedures or accomplishing repetitive-type tasks in a production-orientented environment should also be emphasized. The most ideal tasks are those in which the required inputs, outputs, and processing methods are well defined. This is not to imply that the tasks have to be simple and straightforward; technically challenging tasks are also possible and recommended. As always, the paraprofessional should be under direct and close supervision of a degreed engineer (21:2).

Future application areas are as follows: 1) flight and mission planning--this includes any launch/ascent, on-orbit, and de-orbit trajectory design for a space or satellite system. All tasks should be consistent with the mission groundrules and constraints, and the degree of paratechnical involvement could vary depending on the mission phase being planned; 2) software engineering--including software conversion coding, configuration control, library and database maintenance, and software change and discrepancy requests. This could also involve rehosting of software onto new mainframe computers, making it more transportable, and some limited amount of verification/validation and documentation. Software engineers would be used to initially define and solve the problem, and then the remaining iterative tasks would be turned over to paraprofessionals. Instruction of engineers by computer lab specialists trained in many different systems would also fall into this category; 3) realtime mission console operations--this is an area within the Air Force, as earlier discussed, that is almost exclusively supported by professional engineering contractors. From the NASA/JSC example, primary console positions are manned by engineers, but backroom consoles and functions which augment and support the front room can easily be staffed during simulations and realtime operations by trained technical para-engineers, under the supervision of one or two engineers. With the numerous amount of DOD satellite ground stations and mission control centers in existence, this application could especially be cost persuasive; 4) product and task management--this would involve the scheduling, tracking, collecting, and distributing of hundreds of data products for any large task (21:5). This is probably the best example of an input-output repetitive-type assignment; 5) engineering parametric analyses--any type where the generation and presentation of large amounts of data is required would be an excellent task (21:5).

A sixth area of application is the current leading DOD space endeavor, the Strategic Defense Initiative. Over the next five years, its cost is estimated to be $26 billion (10:9). Current efforts primarily involve research and development (R&D), where engineering tasks are not repetitive and require high levels of engineering judgment. However, using current Space Station efforts as an example, it is highly probable that some small percentage of the present SDI budget could be saved if the government made better assessments of task skills required. Looking to the future, any current planning for an SDI operational era should definitely include the use of paratechnical personnel. The transfer of military space program operations to a workforce comprised of only engineers should be reassessed. NASA has already made some early estimates which show Space Station costs for 24 hour operations are too prohibitive without the use of paratechnical assistance. NASA's Space Station operational concept is currently being influenced to include this type of skill mix (24:--). As SDI costs continue to grow and programs are curtailed or cut back, the program can hardly afford to neglect a potential cost saver. Decisions made now obviously effect future program operations.

The key to successful concept application is to provide the paraprofessional with the proper tools and environment. Too often, computer systems are developed which can only be used by engineers, or the people who developed them. To insure a successful paratechnical workforce, more time must be spent on operational concepts and approaches, and developing computer systems based on user specifications (24:--).

POTENTIAL DIFFICULTIES AND SOLUTIONS

As with all new ideas, difficulties exist. Since training is a key area, this could pose a problem if not done right. Many technical specialities will have to be taught, as the para-engineer is required to be an expert in his area. No expense should be spared in insuring this workforce is technically skilled to do the job.

Another potential area of difficulty could be a less than eager response from established engineering contractors in the space industry. Lowering engineering manpower costs will also lower contract profit or fee. The fact that an engineering firm is employing a small cadre of paratechnicals could also be discerned as jeopardizing that company's chances at future DOD high-tech contracts. If employing the most engineers and making the most profits is the primary goal of a company, then this concept will be perceived as counter-productive. On the other hand, considering that the idea behind a paratechnical concept is to make engineers more productive, then similar company profit goals could still be realized. (How much productivity could be increased is hard to quantify, but one [termed conservative] estimate is that engineering output could be doubled) (25:--). As money is saved, new contracts are possible that might have been financially abandoned, thus securing a stronger defense for the United States.

Security requirements must always be addressed for DOD programs. The utilization of a paratechnical workforce in a DOD secure environment can be demonstrated by the following points. First, in any classified environment there are several categories of workers, such as secretaries, editors, artists, and janitors, other than engineers, who possess security clearances. Second, approximately 80 percent of the Barrios paratechnicals at NASA/JSC had security clearances for DOD classified Shuttle missions (24:--), and they performed this duty in a DOD secure area. The fact that a job is classified should never provide justification for an engineer performing a task that could be done by a paratechnical.

SUMMARY

This chapter has shown that in a competitive space industry environment, government advocation of an engineering and paratechnical skill mix can be a costworthy proposal. If doctors, lawyers, and other vocations can do it, why can't the engineering profession? Besides lowering costs, employment of paraprofessionals produces benefits for the engineering staff. They are relieved from routine tasks and made available for more productive and challenging duties. The skill mix requested by the government in an RFP should be soundly based and varied depending on specific task descriptions. In order to succeed, the concept has to be enthusiastically received, and jointly applied by the government and the space defense contractor industry.

Chapter Six

CONCLUSION

SUMMARY

In 1986, the National Commission on Space proposed a US space agenda for the next 50 years. In its report, "Pioneering the Space Frontier," the Commission proposed numerous goals for better understanding and explaining the inner solar system and stimulating space enterprise and industry. The report went further to say "that accomplishment of these goals demands that the US make long-range committments. . . [in] creating systems and institutions to provide low cost access to the space frontier. Significant payoffs could result. . . by 'pulling through' advances in science and technology of critical importance to the nation's future economic strength and security" (11:2). The creation of an engineering paraprofessional workforce and its widespread use will indeed provide lower cost access to space and allow the United States to pursue more technologically advanced civilian and national security programs. Abandoned by industry in the 1950s, the time has come to resurrect this concept for the benefit of industry, the government, education, and the future. If the drain on our engineering manpower base continues, the United States could lose its competitiveness with the rest of the world in space, particularly the Soviet Union.

In the course of researching this report, the author found that very little written information on the subject of paraprofessionals is available in the engineering private sector, and none was found through any military channels or libraries. Coupled with the knowlegde of the NASA successful experience, the author was moved to write this report in order to raise the awareness of military, government, and industry leaders. As this paper has shown, there are many technical areas that could benefit from paraprofessional application. Potential results are increased job satisfaction, higher morale and motivation, and greater workforce stability. Production and operational procedures become better defined, while a greater portion of the work community is allowed to contribute to the technical effort. If the resulting cost savings for one contract reaches into millions of dollars, how many billions of dollars can be saved from the hundreds of future engineering manpower contracts?

RECOMMENDATIONS

If advances in this area are to be made however, a few critically important hurdles must be faced. The subject of engineering manpower misuses must first be discussed up front to afford all a better understanding of the problem. The USAF must then lead the way for government advocation of a more balanced skill mix of engineers and engineering paraprofessionals, and together with industry agree on a sound means for institutionalizing the concept. Industry cooperation is vital; they must be convinced this will extend their current engineering capability. The author proposes that the most successful companies will be those employing the concept correctly. Once implemented, industry "management must clearly delineate [the paraprofessionals] purpose and functions relative to the professionals they will be working with and for. This should begin in the early stages through orientation sessions with the engineers" (29:--). A key element for success is the design, delivery, and use of production-oriented computer systems. These tools are essential to the paratechnical environment in which accompanying skill levels will be most effective (24:--). Another critical hurdle is training. Companies must give this their highest support. It also provides them with an excellent opportunity to stimulate the education and morale of their workforce.

The original scope of this report also included the advocacy of the paratechnical concept within the military structure of the Air Force. Para-engineering training and utilization of noncommissioned officers (NCOs) in critically manned officer engineering fields is a viable answer to alleviate shortfalls. Because of recent congressional manpower directives aimed at reducing officer personnel strength, this application could be especially well-timed. Secretary of the Air Force Edward C. "Pete" Aldridge, Jr. expressed his concerns about Air Force manpower at Randolph AFB in October 1986: "We're getting new missions but, unfortunately, we aren't getting the manpower increases necessary to man those missions. . . . We're also looking at contracting out those non-essential functions so we can use our people as effectively as we can" (2:1). Consolidated Space and Operations Center planning at Air Force Space Command should consider some degree of NCO paratechnical use (in lieu of officers) as console operations manpower for future satellite programs. Therefore, the author additionally recommends that a follow-on report be considered to analyze current and future applications of Air Force NCO paratechnicals.

A FINAL THOUGHT

A series of letters to the editor of Aviation Week and Space Technology appeared in 1984 and 1985 concerning engineering productivity and manpower alternatives. In answer to an editorial on the technical demands of the SDI (10:9), a writer pointed out that "the most serious impact of this expenditure will be on the nation's pool of scientific and technical personnel" (12:104). Higher salaries are inevitable in order to lure engineers away from current jobs to increase corporate competiveness. A third writer stated:

If you assume we must continue doing business as usual. . . that more engineers must be educated to reduce the shortage of engineers, then this will lead to runaway salaries, ruin the economy and make SDI impractical. [What we must do is] explore the option of doing business differently. . . if we change the way we do business a tad, there would not be a shortage of engineers, and we could take on several SDI-sized projects (8:140).

To meet the challenges of space in the 1990s this country must change its way of doing business. "Engineering extenders" may provide the key to unlock this future. Widespread integration of this workforce into the engineering community may prove to be not just an innovation, but also a necessity if complex operational and man-intensive programs such as SDI are to survive.

"Perhaps this is a way that we can simultaneously raise the technical awareness of the general population, provide technical career opportunities for many who otherwise might not get the chance, and increase the productivity of our engineers" (23:6). The use of engineering paraprofessionals is on the cutting edge of the future--the United States Air Force must meet this challenge!

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